# Chapter F3: Evaluation of I&E Data

CHAPTER CONTENTS



This chapter presents the results of EPA's evaluation of potential impingement and entrainment (I&E) of aquatic organisms in Mount Hope Bay resulting from the CWIS of Brayton Point. The focus of EPA's evaluation was the potential impacts of Brayton Point's current operations on relatively healthy fish populations. Because fish populations in Mount Hope Bay are currently depressed well below historical levels, EPA based its evaluation on the most comprehensive historical time series of I&E data for Brayton Point (1974-1983) and adjusted these rates for the facility's current technologies and operations. It should be noted, however, that using pre-1984 data still probably produces an underestimate of I&E levels because there is data suggesting that the plant contributed to a declining fishery even before 1984, though the decline accelerated precipitously after 1984. Unfortunately, there is no Mount Hope Bay abundance data from before Brayton Point Station began operations to provide true baseline population levels unaffected by the plant. Section F3-1 lists fish species that are impinged and entrained at Brayton Point, and Section F3-2 presents life histories of the most abundant species in the facility's I&E collections. Section F3-3 summarizes the facility's I&E collection methods, and Section F3-4 presents results of EPA's analysis of annual impingement and entrainment. Section F3-5 summarizes the results of EPA's analyses.

## F3-1 Species Impinged and Entrained at Brayton Point

EPA evaluated species known to be impinged and entrained at Brayton Point based on information provided in facility I&E monitoring reports (PG&E Generating and Marine Research Inc., 1999; personal communication, Meredith Simas, Environmental Engineer, Brayton Point Station, January 24, 2002). Approximately 18 different species have been identified in Brayton Point's I&E collections since monitoring began in 1972. At least 10 (56 percent) of these species have commercial and/or recreational value. Table F3-1 lists species identified in the facility's I&E collections. EPA evaluated all the species impinged and entrained at Brayton Point, except a group of unidentified impinged fish species.

**Table F3-1: Aquatic Species Identified in I&E Collections by Brayton Point**

| Common Name | Scientific Name | Commercial | Recreational | Forage |
|---|---|---|---|---|
| Alewife | *Alosa pseudoharengus* | | | X |
| American sand lance | *Ammodytes americanus* | | | X |
| Atlantic menhaden | *Brevoortia tyrannus* | X | | |
| Atlantic silverside | *Menidia menidia* | | | X |
| Bay anchovy | *Anchoa mitchilli* | | | X |
| Blueback herring | *Alosa aestivalis* | | | X |
| Butterfish | *Peprilus triacanthus* | X | | |
| Hogchoker | *Trinectes maculatus* | | | X |
| Rainbow smelt | *Osmerus mordax mordax* | X | | |
| Scup | *Stenotomus chrysops* | X | X | |
| Seaboard goby | *Gobiosoma ginsburgi* | | | X |
| Silver hake | *Merluccius bilinearis* | X | | |
| Striped killifish | *Fundulus majalis* | | | X |
| Tautog | *Tautoga onitis* | X | X | |
| Threespine stickleback | *Gasterosteus aculeatus aculeatus* | | | X |
| Weakfish | *Cynoscion regalis* | X | X | |
| White perch | *Morone americana* | X | X | |
| Windowpane | *Scophthalmus aquosus* | X | | |
| Winter flounder | *Pleuronectes americanus* | X | X | |

*Sources:* PG&E Generating and Marine Research Inc., 1999; Matt Camisa, Fisheries Supervisor, Massachusetts DMF, Personal Communication, January 31, 2002; personal communication, Meredith Simas, Environmental Engineer, Brayton Point Station, January 24, 2002.

## F3-2 Life Histories of Major Species Impinged and Entrained

### Alewife (*Alosa pseudoharengus*)

Alewife is a member of the herring family, Clupeidae, and ranges along the Atlantic coast from Newfoundland to North Carolina (Scott and Crossman, 1998). Alewife tend to be more abundant in the mid-Atlantic and along the northeastern coast. They are anadromous, migrating inland from coastal waters in the spring to spawn. Adult alewife overwinter along the northern continental shelf, settling at the bottom in depths of 56 to 110 m (184 ft to 361 ft) (Able and Fahay, 1998). Adults feed on a wide variety of food items, while juveniles feed mainly on plankton (Waterfield, 1995).

Alewife has been introduced to a number of lakes to provide forage for sportfish (Jude et al., 1987b). Ecologically, alewife is an important prey item for many fish, and commercial landings of river herring along the Atlantic coast have ranged from a high of 33,974 metric tons (74.9 million lb) in 1958 to a low of less than 2,268 metric tons (5 million lb) in recent years (Atlantic States Marine Fisheries Commission , 2000b).

Spawning is temperature-driven, beginning in the spring as water temperatures reach 13 to 15 ˚C (55 to 59 ˚F) and ending when they exceed 27 ˚C (80.6 ˚F) (Able and Fahay, 1998). Spawning takes place in the upper reaches of coastal rivers, in slow-flowing sections of slightly brackish or freshwater.

Females lay demersal eggs in shallow water less than 2 m (6.6 ft) deep (Wang and Kernehan, 1979). They may lay from 60,000 to 300,000 eggs at a time (Kocik, 2000). The demersal eggs are 0.8 to 1.27 mm (0.03 to 0.05 in.) in diameter. Larvae hatch at a size of approximately 2.5 to 5.0 mm (0.1 to 0.2 in.) total length (Able and Fahay, 1998). Larvae remain in the upstream spawning area for some time before drifting downstream to natal estuarine waters. Juveniles exhibit a diurnal vertical migration in the water column, remaining near the bottom during the day and rising to the surface at night (Fay et al., 1983a). In the fall, juveniles move offshore to nursery areas (Able and Fahay, 1998).

Maturity is reached at an age of 3 to 4 years for males, and 4 to 5 years for females (Able and Fahay, 1998). The average size at maturity is 265 to 278 mm (10.4 to 10.9 in.) for males and 284 to 308 mm (11.2 to 12.1 in.) for females (Able and Fahay, 1998). Alewife can live up to 8 years, but the average age of the spawning population tends to be 4 to 5 years (Waterfield, 1995; Public Service Electric and Gas Company, 1999c).

**ALEWIFE**
***(Alosa pseudoharengus)***

**Family:** Clupeidae (herrings).

**Common names:** River herring, sawbelly, kyak, branch herring, freshwater herring, bigeye herring, gray herring, grayback, white herring.

**Similar species:** Blueback herring.

**Geographic range:** Along the western Atlantic coast from Newfoundland to North Carolina.[a]

**Habitat:** Wide-ranging, tolerates fresh to saline waters, travels in schools.

**Lifespan:** May live up to 8 years.[b,c]

**Fecundity:** Females may lay from 60,000 to 300,000 eggs at a time.[d]

**Food source:** Small fish, zooplankton, fish eggs, amphipods, mysids.[c]

**Prey for:** Striped bass, weakfish, rainbow trout.

**Life stage information:**

***Eggs:*** *demersal*
- Found in waters less than 2 m (6.6 ft) deep.[d]
- Are 0.8 to 1.27 mm (0.03 to 0.05 in.) in diameter.[f]

***Larvae:***
- Approximately 2.5 to 5.0 mm (0.1 to 0.2 in.) at hatching.[f]
- Remain in upstream spawning area for some time before drifting downstream to natal estuarine waters.

***Juveniles:***
- Stay on the bottom during the day and rise to the surface at night.[g]
- Emigrate to ocean in summer and fall.[f]

***Adults:*** *anadromous*
- Reach maturity at 3-4 years for males and 4-5 years for females.[f]
- Average size at maturity is 265-278 mm (10.4-10.9 in.) for males and 284-308 mm (11.2-12.1 in.) for females.[f]
- Overwinter along the northern continental shelf.[f]

[a] Scott and Crossman, 1998.
[b] PSEG, 1999c.
[c] Waterfield, 1995.
[d] Kocik, 2000.
[e] Wang and Kernehan, 1979.
[f] Able and Fahay, 1998.
[g] Fay et al., 1983a.
Fish graphic courtesy of New York Sportfishing and Aquatic Resources Educational Program, 2001.

## Atlantic menhaden (*Brevoortia tyrannus*)

The Atlantic menhaden, a member of the Clupeidae (herring) family, is a eurohaline species, occupying coastal and estuarine habitats. It is found along the Atlantic coast of North America, from Maine to northern Florida (Hall, 1995). Adults congregate in large schools in coastal areas; these schools are especially abundant in and near major estuaries and bays. They consume plankton, primarily diatoms and dinoflagellates, which they filter from the water through elaborate gill rakers. In turn, menhaden are consumed by almost all commercially and recreationally important piscivorous fish, as well as by dolphins and birds (Hall, 1995).

The menhaden fishery, one of the most important and productive fisheries on the Atlantic coast, is a multimillion-dollar enterprise (Hall, 1995). Menhaden are considered an “industrial fish” and are used to produce products such as paints, cosmetics, margarine (in Europe and Canada), and feed, as well as bait for other fisheries. Landings in New England declined to their lowest level of approximately 2.7 metric tons (5,952 lb) in the 1960s because of overfishing. Since then, landings have varied, ranging from approximately 240 metric tons (529,100 lb) in 1989 to 1,069 metric tons (2,356,742 lb) in 1998 (Personal Communication, National Marine Fisheries Service, Fisheries Statistics and Economics Division, Silver Spring, Maryland, March 19, 2001).

Atlantic menhaden spawn year round at sea and in larger bays (Scott and Scott, 1988). Spawning peaks during the southward fall migration and continues throughout the winter off the North Carolina coast. There is limited spawning during the northward migration and during summer months (Hall, 1995). The majority of spawning occurs over the inner continental shelf, with less activity in bays and estuaries (Able and Fahay, 1998).

Females mature just before age 3, and release buoyant, planktonic eggs during spawning (Hall, 1995). Atlantic menhaden annual egg production ranges from approximately 100,000 to 600,000 eggs for fish age 1 to age 5 (Dietrich, 1979). Eggs are spherical and between 1.3 to 1.9 mm (0.05 to 0.07 in.) in diameter (Scott and Scott, 1988).

Larvae hatch after approximately 24 hours and remain in the plankton. Larvae hatched in offshore waters enter the Delaware Estuary 1 to 2 months later to mature (Hall, 1995). Juveniles then migrate south in the fall, joining adults off North Carolina in January (Hall, 1995). Water temperatures below 3 ˚C (37 ˚F) kill the larvae, and therefore larvae that fail to reach estuaries before the fall are more likely to die than those arriving in early spring (Able and Fahay, 1998). Larvae hatchout at 2.4 to 4.5 mm (0.09 to 0.18 in.). The transition to the juvenile stage occurs between 30 and 38 mm (1.2 and 1.5 in.) (Able and Fahay, 1998). The juvenile growth rate in some areas is estimated to be 1 mm (0.04 in.) per day (Able and Fahay, 1998).

During the fall and early winter, most menhaden migrate south off of the North Carolina coast, where they remain until March and early April. They avoid waters below 3 ˚C, but can tolerate a wide range of salinities from less than 1 percent up to 33-37 percent (Hall, 1995). Sexual maturity begins at age 2, and all individuals are mature by age 3 (Scott and Scott, 1988).

Adult fish are commonly between 30 and 35 cm (11.8 and 13.8 in.) in length. The maximum age of a menhaden is approximately 7 to 8 years (Hall, 1995), although individuals of 8-10 years have been recorded (Scott and Scott, 1988).

**ATLANTIC MENHADEN**
**(*Brevoortia tyrannus*)**

**Family:** Clupeidae (herrings).

**Common names:** menhaden, bunker, fatback, bugfish.

**Similar species:** Gulf menhaden, yellowfin menhaden.

**Geographic range:** From Maine to northern Florida along the Atlantic coast.[a]

**Habitat:** Open-sea, marine waters. Travels in schools.[b]

**Lifespan:**
- Approximately 7 to 8 years.[a]

**Fecundity:**
- Females may produce between 100,000 to 600,000 eggs.[c]

**Food Source:** Phytoplankton, zooplankton, annelid worms, detritus[b]

**Prey for:** Sharks, cod, pollock, hakes, bluefish, tuna, swordfish, seabirds, whales, porpoises.[b]

**Life stage information:**

***Eggs:*** *pelagic*
- Spawning takes place along the inner continental shelf, in open marine waters.[d]
- Eggs hatch after approximately 24 hours.

***Larvae:*** *pelagic*
- Larvae hatch out at sea, and enter estuarine waters 1 to 2 months later.[a]
- Remain in estuaries through the summer, emigrating to ocean waters as juveniles in September or October.[d]

***Adults:***
- Congregate in large schools in coastal areas.
- Spawn year round.[b]

[a] Hall, 1995.
[b] Scott and Scott, 1988.
[c] Dietrich, 1979.
[d] Able and Fahay, 1998.
Fish graphic from South Carolina Department of Natural Resources, 2001.

## Atlantic silverside (*Menidia menidia*)

The Atlantic silverside is a member of the silverside family, Atherinidae. Its geographic range extends from coastal waters of New Brunswick to northern Florida (Fay et al., 1983b), but it is most abundant between Cape Cod and South Carolina (Able and Fahay, 1998). Atlantic silversides inhabit sandy seashores and the mouths of inlets (Froese and Pauly, 2001). Silversides are an important species of forage fish, eaten by valuable fishery species such as striped bass (*Morone saxatilis*), bluefish (*Pomatomus salatrix*), weakfish (*Cynoscion regalis*), and Atlantic mackerel (*Scomber scombrus*) (Fay et al., 1983b; McBride, 1995).

Atlantic silversides spawn in the upper intertidal zone during spring and summer. Spawning appears to be stimulated by new and full moons, in association with spring tides. On average, females produce 4,500 to 5,000 demersal eggs per spawning season, which may include four to five separate spawning bouts (Fay et al., 1983b). The eggs are 0.9 to 1.2 mm (0.04 to 0.05 in.) in diameter. Larvae range in size from 5.5 to 15.0 mm (0.2 to 0.6 in.) (Fay et al., 1983b). The sex of Atlantic silversides is determined during the larval stage, at approximately 32 to 46 days after hatching. Water temperatures between 11 and 19 ˚C (52 and 66 ˚F) produce significantly more females, whereas temperatures between 17 and 25 ˚C (63 and 77 ˚F) produce significantly more males (Fay et al., 1983b).

Juveniles occur in estuaries during the summer months, occupying intertidal creeks, marshes, and shore zones of bays and estuaries. Silversides typically migrate offshore in the winter (McBride, 1995). In studies of seasonal distribution in Massachusetts, all individuals left inshore waters during winter months (Able and Fahay, 1998).

The diet of juveniles and adults consists of copepods, mysids, amphipods, cladocerans, fish eggs, squid, worms, molluscs, insects, algae, and detritus (Fay et al., 1983b). Atlantic silversides feed in large schools, preferring gravel and sand bars, open beaches, tidal creeks, river mouths, and marshes (Fay et al., 1983b).

Silversides live for only 1 or 2 years, usually dying after completing their first spawning (Fay et al., 1983b). Adults can reach sizes of up to 15 cm (5.9 in.) in total length (Froese and Pauly, 2001).

**ATLANTIC SILVERSIDE**
**(*Menidia menidia*)**

**Family:** Atherinidae (silversides).

**Common names:** Spearing, sperling, green smelt, sand smelt, white bait, capelin, shiner.[a]

**Similar species:** Inland silverside (*Menidia beryllina*).[a]

**Geographic range:** New Brunswick to northern Florida.[a]

**Habitat:** Sandy seashores and the mouths of inlets.[b]

**Lifespan:** One or 2 years. Often die after their first spawning.[a]

**Fecundity:** Females produce an average of 4,500 to 5,000 eggs per spawning season.[a]

**Food Source:** Zooplankton, fish eggs, squid, worms, molluscs, insects, algae, and detritus.[a]

**Prey for:** Striped bass, bluefish, weakfish, and Atlantic mackerel.[a,c]

**Life stage information:**

***Eggs:*** *demersal*
- Found in shallow waters of estuarine intertidal zones.[a]
- Can be found adhering to submerged vegetation.[a]

***Larvae:***
- Range from 5.5 to 15.0 mm (0.2 to 0.6 in.) in size.[a]
- Sex is determined during the larval stage by the temperature regime. Colder temperatures tend to produce more females, and warmer temperatures produce more males.[a]

***Adults:***
- Overwinter in offshore marine waters.[d]
- Can reach sizes of up to 15 cm (5.9 in.) total length.[d]

[a] Fay et al., 1983b.
[b] Froese and Pauly, 2001.
[c] McBride, 1995.
[d] Able and Fahay, 1998.
Fish graphic from Government of Canada, 2001.

## Tautog (*Tautoga onitis*)

The tautog is a member of the Labridae family, found in coastal areas from New Brunswick south to South Carolina. It is most abundant from Cape Cod, Massachusetts, to the Delaware Estuary (Atlantic States Marine Fisheries Commission, 2000e). Tautog are most frequently found close to shore, preferring rocky areas or other discontinuities such as pilings, jetties, or wrecks and salinities of greater than 25 ppt (Jury et al., 1994). They generally consume mussels, small crustaceans, and other molluscs (Steimle and Shaheen, 1999).

Tautog have historically supported a primarily recreational fishery. Since 1980, landings have averaged about 3,700 metric tons (8.1 million lb), with recreational catches accounting for 90 percent of the total (Atlantic States Marine Fisheries Commission, 2000e). The majority of Tautog are harvested by hook and line from private boats (Auster, 1989); however, there are also significant charter and party boat fisheries. Although commercial landings accounted for only 8.7 percent of the total from 1982 to 1991, commercial fishing has been increasing because of higher market prices (Atlantic States Marine Fisheries Commission, 2000h). There is evidence that the fishery is declining, with lower recreational and commercial catch rates. A survey conducted in Narragansett Bay in 1994 showed the lowest abundance of tautog ever recorded. Tautog are susceptible to overfishing, particularly because they experience slow growth and reproduction and tend to be easily found near wrecks and rock piles (Atlantic States Marine Fisheries Commission, 2000e).

Tautog migrate inshore in the spring to spawn in inshore waters. Spawning generally occurs between mid-May and August, peaks in June (Auster, 1989), and primarily takes place at the mouths of estuaries and along the inner continental shelf. In Narragansett Bay, tautog are known to return to the same spawning sites in the upper estuary each year. Fecundity increases with age until approximately age 16, when it begins to decline (Steimle and Shaheen, 1999). Females between 3 and 20 years were documented to contain between 5,000 and 673,500 mature eggs. The eggs are buoyant, and hatch out in approximately 2 to 3 days (Auster, 1989).

Larvae hatch out at 2 to 4 mm (0.079 to 0.157 in.) and migrate vertically in the water column, surfacing during the day and remaining near the bottom at night. Tautog are the most abundant larval species in Narragansett Bay. As they get older, they become more benthic (Steimle and Shaheen, 1999). Small juveniles will remain in estuaries year-round, in a home range of only several hundred meters, becoming torpid over the winter (Jury et al., 1994), while larger ones will join adults in deeper water. Small juveniles prefer vegetated habitats in depths of less than 1 m (3.3 ft) and are not observed in Narragansett Bay water deeper than 9 m (30 ft). Older juveniles and adults inhabit reef-like habitats that provide some type of cover (Steimle and Shaheen, 1999).

Tautog do not tend to migrate far offshore; however, adults move to deeper water in the fall, responding to decreases in temperature. Although they move to waters as deep as 45 m (148 ft), tautog select areas with rugged topography for cover. Adults return to coastal waters and estuaries to spawn when waters warm in the spring. Maturity is reached at about 3 to 4 years of age. Age 7 tautogs in Rhode Island had mean lengths of 348 mm (14 in.) for males and 301 mm (12 in.) for females. Males may live for over 30 years, while females may live to about 25 years of age (Steimle and Shaheen, 1999).

**TAUTOG**
**(*Tautoga onitis*)**

**Family:** Labridae (wrasses).

**Common names:** tautog, blackfish, white chin, chub, black porgy.[a]

**Similar species:** Cunner (*Tautogolabrus adspersus*).

**Geographic range:** Most abundant from Cape Cod, Massachusetts to the Delaware Estuary.[b]

**Habitat:** Rocky shoals around coastal shores.[c]

**Lifespan:** Maturity is reached at about 3 to 4 years. Maximum age of over 30 years for males, 25 years for females.[a]

**Fecundity:** Mature females may contain between 5,000 and 673,500 mature eggs.[d]

**Food Source:** Juveniles feed on amphipods and copepods. Adults feed mainly on blue mussels, small crustaceans, and other molluscs.[a]

**Prey for:** Smooth dogfish, barndoor skate, red hake, sea raven, goosefish, striped bass, silver hake, bluefish, seabirds.[a]

**Life stage information**:

***Eggs:*** *buoyant*
- Hatch out in 2 to 3 days.[a]

***Larvae:*** *pelagic*
- Young larvae migrate vertically in the water column, surfacing during the day and remaining near the bottom at night.[a]

***Juveniles:*** *benthic*
- Small juveniles prefer vegetated areas in depths less than 1 m (3.3 ft).[a]
- Larger juveniles prefer covered, reef-like habitats.[a]

***Adults:***
- Inhabit reef-like habitats that provide some type of cover.[a]
- Migrate inshore in late spring to spawn at the mouths of estuaries and along the inner continental shelf.[a]

[a] Steimle and Shaheen, 1999.
[b] Atlantic States Marine Fisheries Commission, 2000e.
[c] Scott and Scott, 1988.
[d] Auster, 1989.
Fish graphic from: State of Maine Division of Marine Resources, 2001c.

## Windowpane (*Scophthalmus aquosus*)

Windowpane is a member of the Scophthalmidae family (left-eye flounders) found from the Gulf of St. Lawrence to Florida, inhabiting estuarine and shallow continental shelf waters less than 56 m (184 ft) deep (Able and Fahay, 1998). They have been found in areas with muddy or sandy bottoms, water temperatures ranging from 0 to 24ºC (0 to 75 ºF), and salinities of 5.5 to 36 ppt (Chang et al., 1999).

Spawning occurs over the continental shelf and in estuaries, but not in waters over 20 ºC (68 ºF) (Kaiser and Neuman, 1995). The timing of spawning varies with location: in Mid-Atlantic Bight waters, spawning occurs from April through December, peaking in May and October, while on Georges Bank spawning occurs during summer and peaks in July and August (Hendrickson, 2000). The estimated average lifetime fecundity of females is 100,000 eggs (New England Power Company and Marine Research Inc., 1995). Eggs are buoyant and hatch out in 8 days at a water temperature of 11°C (52 ºF) (Chang et al., 1999). Eggs and larvae are planktonic, but movements are poorly understood. Between 6.5 and 13.0 mm (0.256 and 0.512 in.), eye migration occurs and the body becomes more laterally compressed (Able and Fahay, 1998). Juveniles appear to use estuaries as nursing areas, and then move to offshore waters in the fall (Kaiser and Neuman, 1995).

Although windowpane have been found to migrate 130 km (81 miles) in a few months, most researchers agree that windowpane generally do not migrate long distances (Chang et al., 1999).

Windowpane reach sexual maturity at age 3 or 4 (Hendrickson, 2000). Adults reach a maximum length of approximately 46 cm (18 in.), and may live up to 7 years (Scott and Scott, 1988).

While windowpane has not been a particularly important commercial fish, it may become more so as stocks of summer flounder are overfished. Commercial catches began in 1943, and through 1975 windowpane was harvested as part of an industrial fishery. Landings in southern New England peaked in 1985 at 2,100 metric tons (4.6 million lb), decreased to a low of 100 metric tons (0.2 million lb) in 1995, and have remained below 200 metric tons (0.4 million lb) since then. Populations have also decreased since the 1980's, and overfishing is suspected as a main cause (Hendrickson, 2000).

**WINDOWPANE**
**(*Scophthalmus aquosus*)**

**Family:** Scophthalmidae (left-eye flounder).

**Common names:** windowpane.

**Similar species:** turbot (*Scophthalmus maximus*), brill (*Scophthalmus rhombus*).

**Geographic range:** From the Gulf of St. Lawrence to Florida.[a]

**Habitat:** Estuarine and shallow continental shelf waters of depths less than 56 m (184 ft).[a]

**Lifespan:** Approximately 7 years.[b]

**Fecundity:** Average lifetime fecundity of 100,000 eggs.[c]

**Food Source:** Young consume mysids; adults feed on sand shrimp, small fish (up to 10 cm), crustaceans, molluscs, and seaweed.

**Prey for:** Spiny dogfish, thorny skate, goosefish, Atlantic cod, black sea bass, weakfish, and summer flounder.[d]

**Life stage information:**

***Eggs:*** *buoyant*
- Eggs are buoyant and hatch out in 8 days at a water temperature of 11 ˚C.[d]

***Larvae:*** *pelagic*
- Eye migration occurs and the body becomes more laterally compressed.[d]

***Juveniles:***
- Use estuaries as nursing areas, returning to offshore waters in the fall.[e]

***Adults:***
- Reach a maximum length of approximately 46 cm.[b]
- Seasonally migrate to deeper waters in late autumn to overwinter.[d]

[a] Able and Fahay, 1998.
[b] Scott and Scott, 1988.
[c] New England Power Company and Marine Research Inc., 1995.
[d] Chang et al., 1999.
[e] Kaiser and Neuman, 1995.
Fish graphic from NEFSC, 2001.

## Winter flounder (*Pleuronectes americanus*)

Winter flounder is a benthic flatfish of the family Pleuronectidae (righteye flounders), which is found in estuarine and continental shelf habitats. Its range extends from the southern edge of the Grand Banks south to Georgia (Buckley, 1989b). It is a bottom feeder, occupying sandy or muddy habitats and feeding on bottom-dwelling organisms such as shrimp, amphipods, crabs, urchins, and snails (Froese and Pauly, 2001).

Both commercial and recreational fisheries for winter flounder are important. U.S. commercial and recreational fisheries are managed under the New England Fishery Management Council's Multispecies Fishery Management Plan and the Atlantic States Marine Fisheries Commission's Fishery Management Plan for Inshore Stocks of Winter Flounder (NEFSC, 2000d). Three groups are recognized for management and assessment purposes: Gulf of Maine, Southern New England-Mid Atlantic, and Georges Bank. Management currently focuses on reducing fishing levels to reverse declining trends and rebuild stocks. The Gulf of Maine stock is currently considered overfished (NEFSC, 2000d). Although improvements in stock condition will depend on reduced harvest, the long-term potential catch (maximum sustainable yield) has not been determined.

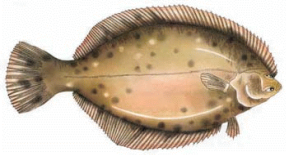
The winter flounder is essentially nonmigratory, but there are seasonal patterns in movements within the estuary. Winter flounder south of Cape Cod generally move to deeper, cooler water in summer and return to shallower areas in the fall, possibly in response to temperature changes (Howe and Coates, 1975; Scott and Scott, 1988).

Spawning occurs between January and May in New England, with peaks in the Massachusetts area in February and March (Bigelow and Schroeder, 1953). Spawning habitat is generally in shallow water over a sandy or muddy bottom (Scott and Scott, 1988). Adult fish tend to leave the shallow water in autumn to spawn at the head of estuaries in late winter. The majority of spawning takes place in a salinity range of 31 to 33 ppt and a water temperature range of 0 to 3 ˚C (32 to 37 ˚F). Females will usually produce between 500,000 and 1.5 million eggs annually, which sink to the bottom in clusters. The eggs are about 0.74 to 0.85 mm (approximately 0.03 in.) in diameter, and hatch in approximately 15 to 18 days (Bigelow and Schroeder, 1953).

Larvae are about 3.0 to 3.5 mm (0.1 in.) total length when they hatch out. They develop and metamorphose over 2 to 3 months, with growth rates controlled by water temperature (Bigelow and Schroeder, 1953). Larval growth appears to be optimal with a slow increase from spawning temperatures of 2 ˚C (36 ˚F) to approximately 10 ˚C (50 ˚F; Buckley, 1982). Larvae depend on light and vision to feed during the day and do not feed at night (Buckley, 1989b). Juveniles tend to remain in shallow spawning waters, and stay on the ocean bottom (Scott and Scott, 1988).

Fifty percent of females reach maturity at age 2 or 3 in the waters of Georges Bank, while they may not mature until age 5 in more northern areas such as near Newfoundland. Females are generally 22.5 to 31.5 cm (8 to 12.4 in.) long at maturity (Howell et al., 1992).

Winter flounder supports important commercial and recreational fisheries in the area, as it is the thickest and meatiest of the common New England flatfish (Bigelow and Schroeder, 1953). Annual commercial landings in New England declined from 17,083 metric tons (37.7 million lb) in 1981 to 3,223 metric tons (7.1 million lb) in 1994. The harvest has increased somewhat since then, rising to 5,123 metric tons (11.3 million lb) in 2000 (personal communication, National Marine Fisheries Society, Fish Statistics and Economics Division, Silver Spring, MD, January 16, 2002.). Winter flounder is ecologically important as a prey species for larger estuarine and coastal fish such as striped bass (*Morone saxatilis*) and bluefish (*Pomatomus saltatrix*) (Buckley, 1989b).



**WINTER FLOUNDER**
**(*Pleuronectes americanus*)**

**Family:** Pleuronectidae (righteye flounders).

**Common names:** Blackback flounder, lemon sole, black flounder.[a]

**Similar species:** American plaice (*Hippoglossoides platessoides*), European plaice (*P. platessus*).

**Geographic range:** From the southern edge of the Grand Banks south to Georgia.[b]

**Habitat:** Bottom dweller. Found in coastal marine waters.[c]

**Lifespan:** May live up to 15 years.

**Fecundity:** Females produce between 500,000 and 1.5 million eggs annually.[a]

**Food source:** Bottom-dwelling organisms such as shrimp, annelid worms, amphipods, crabs, urchins and snails.[a]

**Prey for:** Striped bass, bluefish.[b]

**Life stage information**:

***Eggs:*** *demersal*
- Approximately 0.74 to 0.85 mm (0.03 in.) in diameter.[a]
- Hatch in approximately 15 to 18 days.[a]

***Larvae:*** *semi-pelagic*
- Approximately 3.0 to 3.5 (0.1 in.) mm total length when they hatch out.[a]

***Juveniles:*** *demersal*
- Once winter flounder enter the juvenile stage, they remain benthic, preferring sandy bottomed substrates.[d]

***Adults***:
- Females mature at ages 2 and 3.[e]
- Migrate seasonally to offshore waters in the summer, and inshore waters in the winter.[b]

[a] Bigelow and Schroeder, 1953.
[b] Buckley, 1989b.
[c] Scott and Scott, 1988.
[d] Grimes et al., 1989.
[e] Howell et al., 1992.
Fish graphic from State of Maine Division of Marine Resources, 2001d.

## F3-3 Brayton Point Generating Station's I&E Sampling Methods

Impingement sampling was conducted from 1972 through 1998. Entrainment sampling has been conducted periodically in the discharge of units 1, 2, and 3 since 1972. The following sections describe these sampling programs.

## F3-3.1 Impingement Monitoring

Impingement sampling of the revolving screens at units 1,2, and 3 was conducted from 1972 through 1998. Sampling was conducted year-round, as long as each unit was in operation (USGen New England, 2001).

The traveling screens for units 1, 2, and 3 have 9.5 mm (0.375 in.) mesh (PG&E National Energy Group, 2001). During impingement sampling, screenwash water was diverted to in-line collection tanks. All fish collected were identified and counted, although counts were reported separately only for selected species; all other species were reported as a group.

From 1972 to 1996, impingement was monitored three times per week by placing a trap in the sluiceway downstream of the revolving screens while the wash system was in operation. All of the fish collected in the trap were counted, identified, and measured. Unit 3 screens, which have the highest impingement rate, were washed three times a day at 8 to 12 hour intervals. Each of the three weekly collections took place at one of these wash periods. Units 1 and 2 were washed once per day, and only two weekly collections were done at these units (New England Power Company and Marine Research Inc., 1998).

Since 1997, the revolving screens have run continuously and are monitored daily. To monitor impingement rates, the collection tank is periodically emptied and left in place for a 4 to 8 hour interval (PG&E Generating and Marine Research Inc., 1999).

To derive annual estimates, the facility extrapolated counts from a weekly sampling period to derive a weekly total (PG&E Generating and Marine Research Inc., 1999). Weekly totals were then summed to estimate an annual total. It should be noted that the impingement data set used (1974-1983) likely represents an underestimate because that time period did not include or record any of the occasional large-scale impingement events for menhaden that have occurred at Brayton Point over the years. For example, in early 2002 an impingement event occurred in which approximately 25,000 menhaden were impinged from January 5 through February 3, 2002, and then another approximately 6,400 were impinged from February 11 to February 16, 2002.

## F3-3.2 Entrainment Monitoring

Entrainment sampling of selected species was conducted in the discharge stream of units 1, 2, and 3 from June 1972 through December 1985. Until the middle of 1984, entrainment was sampled for units 1,2, and 3 only. When unit 4 switched to once-through cooling in 1984, sampling was also conducted near the unit 4 discharge headwall from February through mid-May, except when unit 4 was operating in piggyback mode (see Chapter F2; PG&E Generating and Marine Research Inc.,1999; USGen New England, 2001; PG&E National Energy Group, 2001). Sampling ceased from 1986 through 1991. In January 1992, entrainment sampling was reinitiated during the larval season (February through mid-May) for winter flounder only, as part of an examination of the winter flounder stock decline in Mount Hope Bay (USGen New England, 2001). Initially, winter flounder entrainment was classified only as larvae or eggs, but from 1978 on, four larval stages were classified (PG&E Generating and Marine Research Inc., 1999). Other species were not classified into separate larval stages.

From 1972 to 1979, sampling was conducted monthly from September through February and weekly from March through August. In 1979, the sampling frequency was increased to every 4 to 5 days from March through August (Marine Research Inc. and New England Power Company, 1981). After 1992, the sampling schedule was again changed so that sampling was conducted from February through mid-May every 4 to 5 days.

Sampling techniques have remained generally the same since 1972 (PG&E Generating and Marine Research Inc., 1999). Collection was completed by streaming 0.333 mm (0.01 in.) or 0.505 mm (0.02 in.) mesh, 60 cm (24 in.) diameter plankton nets in the discharge streams of the units. Three samples were taken at each sampling event (PG&E National Energy Group, 2001).

Differences in sampling gear mesh size made it necessary to standardize the entrainment data. Samples from the finer 0.333 mm (0.01 in.) mesh screens were adjusted by the facility to make the data comparable to the 0.505 mm (0.02 in.) mesh screens, because this size mesh was used in the past to develop baywide winter flounder abundance estimates. An adjustment factor derived from a mesh comparison study conducted at Brayton Point in 1994 (New England Power Company & Marine Research Inc., 1995) was used to account for the extrusion of smaller larvae that would have occurred through the larger mesh net.

To derive annual estimates, the facility standardized larval densities to the number of larvae per 100 $m^3$ (26,000 gallons) of water within each sampling day (PG&E Generating and Marine Research Inc., 1999). The facility extrapolated these larval

densities to annual estimates using the reported monthly average circulating water volume. Since 1992, estimates of larval winter flounder entrainment were determined separately for units 1, 2, and 3 combined and for unit 4 alone.

## F3-4 Annual Impingement and Entrainment

There are a number of deficiencies in Brayton Point's time series of I&E data. First, I&E data collected over the past decade or so probably underestimate potential I&E of Mount Hope Bay fish species, since the populations of most fish species in the area are severely depressed (Gibson, 1996). In addition, Brayton Point's entrainment monitoring since 1985 has included only winter flounder. Therefore, to estimate potential I&E at Brayton Point under current operating conditions for as many species as possible, EPA used the most comprehensive historical time series of I&E data for Brayton Point (1974-1983) and adjusted these rates for the facility's current operations.

EPA's adjustment of historical I&E rates to reflect current operations considered (1) the effectiveness of the angled screens on Unit 4, which the facility reports reduce impingement by 55.4%, and (2) the higher current intake flow resulting from the conversion of Unit 4 to once through cooling in 1984 (see Chapter F2 for technical details). EPA applied a scaling factor of 1.142 to impingement and entrainment data to account for the higher current intake flow and a scaling factor of 0.931 to impingement data to account for the angled screen. The flow scaling factor was based on the annualized mean operational flow (Units 1-3) during 1974-1983 of 720 MGD, and the current annualized mean operational flow (Units 1-4) of 822 MGD. The value 822 MGD for current annualized mean operational flow includes consideration of the fact that Unit 4 is operated in piggyback mode during selected months. This flow estimate was derived from records of flow provided by the facility. The use of the scaling factors increased the 1974-1983 entrainment rates by 14.2% and impingement rates by 6.4%.

EPA evaluated its estimates of annual I&E under current Brayton Point operations using the methods described in Chapter A5 of Part A of this document. The species-specific life history values used by EPA for its analyses are presented in Appendix F1. Table F3-2 displays EPA's estimates of annual impingement (numbers of organisms) by species. Table F3-3 displays those numbers expressed as age 1 equivalents, Table F3-4 displays impingement of fishery species as yield lost to fisheries, and Table F3-5 displays annual impingement expressed as production foregone. Tables F3-6 through F3-9 display the same information for entrainment at Brayton Point.

## F3-5 Summary

Table F3-10 summarizes EPA's estimates of annual I&E impacts of Brayton Point's current operations on Mount Hope Bay fish species. Results indicate that, on average, current operations may be expected to result in annual impingement of about 45,000 organisms. This represents 69,329 age 1 equivalents, 5,091 pounds of lost fishery yield, and 2,808 pounds of production foregone each year. Note that impingement losses expressed as age 1 equivalents are higher than raw losses (the actual number of organisms of all life stages that are impinged). This is because the ages of impinged individuals are assumed to be distributed across the interval between the start of year 1 and the start of year 2, and then the losses are normalized back to the start of year 1 by accounting for mortality during this interval (for details see Chapter A5).

Most impinged species are the forage fish hogchoker, Atlantic silverside, alewife, and bay anchovy, and the fishery species silver hake and winter flounder. There have also been episodes of high impingement of Atlantic menhaden, reaching several hundred thousand losses within a few weeks (Phil Colarusso, EPA Region 1, *personal communication*, February 2002). The most recent event, in winter 2002, involved the impingement of over 25,000 Atlantic menhaden. Annual entrainment resulting from current operations is estimated to average over 16.7 billion organisms, representing over 3.8 million age 1 equivalents, 70,410 pounds of lost fishery yield, and 69.5 million pounds of production foregone each year.

Most entrained organisms are the forage species American sand lance, bay anchovy, and seaboard goby and the fishery species winter flounder. The estimated average loss of over a half million age 1 equivalent winter flounder each year is thought to represent most of the local stock of winter flounder according to estimates by the Rhode Island Division of Fish and Wildlife (Phil Colarusso, EPA Region 1, *personal communication*, March 14, 2002).

The economic value of Brayton Point's I&E losses is discussed in Chapters F4 (benefits transfer) and F5 (habitat-based replacement cost). The potential benefits of reducing these losses with the proposed rule are discussed in Chapter F6.

**Table F3-2: EPA's Estimate of Brayton Point Annual Impingement (numbers of organisms) Derived from Historical Impingement Rates Adjusted for Current Operations**

| Year | Alewife | Atlantic Menhaden | Atlantic Silverside | Bay Anchovy | Butterfish | Hogchoker | Rainbow Smelt | Silver Hake | Striped Killifish | Tautog | Threespine Stickleback | Weakfish | White Perch | Window-pane | Winter Flounder |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 2,450 | 12,438 | 4,020 | 859 | 264 | 2,142 | 2,450 | 3,428 | 89 | 215 | 3,468 | 157 | 2,104 | 304 | 17,135 |
| 1975 | 1,928 | 1,681 | 684 | 15,879 | 102 | 1,634 | 129 | 3,691 | 73 | 363 | 1,907 | 307 | 1,571 | 234 | 4,718 |
| 1976 | 5,550 | 897 | 1,347 | 1,470 | 15 | 5,175 | 312 | 1,295 | 429 | 409 | 1,608 | 182 | 4,507 | 348 | 6,314 |
| 1977 | 37,627 | 2,571 | 3,287 | 2,279 | 346 | 22,684 | 591 | 19,065 | 1,898 | 2,709 | 822 | 1,889 | 4,467 | 2,025 | 14,397 |
| 1978 | 3,090 | 1,671 | 17,935 | 684 | 21 | 10,614 | 3,515 | 8,433 | 213 | 2,500 | 1,109 | 468 | 1,319 | 2,548 | 24,941 |
| 1979 | 1,926 | 465 | 5,270 | 5,284 | 87 | 2,983 | 607 | 6,868 | 364 | 338 | 5,134 | 269 | 812 | 1,130 | 4,087 |
| 1980 | 1,080 | 872 | 4,303 | 806 | 740 | 4,438 | 241 | 883 | 576 | 684 | 1,025 | 140 | 786 | 1,540 | 7,891 |
| 1981 | 319 | 36 | 4,740 | 146 | 38 | 1,630 | 412 | 391 | 470 | 780 | 1,057 | 37 | 418 | 2,008 | 5,841 |
| 1982 | 4,986 | 129 | 3,567 | 3,053 | 143 | 16,244 | 267 | 3,130 | 66 | 3,078 | 449 | 1,560 | 803 | 727 | 2,986 |
| 1983 | 1,023 | 0 | 2,690 | 3,036 | 6 | 2,297 | 171 | 1,816 | 0 | 235 | 387 | 22 | 439 | 74 | 2,172 |
| Mean | 5,998 | 2,076 | 4,784 | 3,350 | 176 | 6,984 | 870 | 4,900 | 418 | 1,131 | 1,697 | 503 | 1,723 | 1,094 | 9,048 |
| Minimum | 319 | 0 | 684 | 146 | 6 | 1,630 | 129 | 391 | 0 | 215 | 387 | 22 | 418 | 74 | 2,172 |
| Maximum | 37,627 | 12,438 | 17,935 | 15,879 | 740 | 22,684 | 3,515 | 19,065 | 1,898 | 3,078 | 5,134 | 1,889 | 4,507 | 2,548 | 24,941 |
| SD | 11,240 | 3,736 | 4,839 | 4,662 | 228 | 7,256 | 1,153 | 5,605 | 557 | 1,148 | 1,500 | 661 | 1,546 | 889 | 7,402 |
| Total | 59,980 | 20,760 | 47,842 | 33,496 | 1,762 | 69,840 | 8,695 | 49,001 | 4,178 | 11,310 | 16,967 | 5,032 | 17,225 | 10,939 | 90,481 |

0=Sampled, but none collected.
Wed Feb 13 11:40:28 MST 2002 Raw.losses. IMPINGEMENT; Plant:brayton.projected;
PATHNAME:P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/raw.losses.imp.brayton.projected.csv

**Table F3-3: EPA's Estimate of Annual Impingement at Brayton Point Derived from Historical Impingement Rates Adjusted for Current Operations and Expressed as Age 1 Equivalents**

| Year | Alewife | Atlantic Menhaden | Atlantic Silverside | Bay Anchovy | Butter-fish | Hog-choker | Rainbow Smelt | Silver Hake | Striped Killifish | Tautog | Threespine Stickleback | Weakfish | White Perch | Windowpane | Winter Flounder |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 3,617 | 15,717 | 7,657 | 1,562 | 415 | 3,977 | 3,602 | 4,038 | 122 | 234 | 5,584 | 188 | 2,805 | 367 | 25,756 |
| 1975 | 2,846 | 2,124 | 1,303 | 28,870 | 161 | 3,033 | 189 | 4,349 | 101 | 394 | 3,071 | 366 | 2,094 | 282 | 7,091 |
| 1976 | 8,194 | 1,133 | 2,567 | 2,672 | 23 | 9,609 | 458 | 1,526 | 587 | 445 | 2,589 | 217 | 6,009 | 420 | 9,491 |
| 1977 | 55,547 | 3,249 | 6,261 | 4,144 | 544 | 42,121 | 869 | 22,460 | 2,600 | 2,945 | 1,324 | 2,251 | 5,955 | 2,444 | 21,641 |
| 1978 | 4,562 | 2,111 | 34,161 | 1,243 | 33 | 19,708 | 5,166 | 9,935 | 291 | 2,718 | 1,786 | 558 | 1,758 | 3,076 | 37,489 |
| 1979 | 2,843 | 587 | 10,037 | 9,608 | 137 | 5,539 | 893 | 8,091 | 498 | 368 | 8,268 | 321 | 1,083 | 1,365 | 6,143 |
| 1980 | 1,595 | 1,102 | 8,196 | 1,466 | 1,166 | 8,240 | 355 | 1,040 | 790 | 743 | 1,651 | 167 | 1,048 | 1,859 | 11,861 |
| 1981 | 471 | 46 | 9,028 | 265 | 60 | 3,027 | 605 | 461 | 644 | 848 | 1,702 | 44 | 557 | 2,424 | 8,779 |
| 1982 | 7,360 | 163 | 6,794 | 5,551 | 224 | 30,162 | 392 | 3,687 | 90 | 3,346 | 723 | 1,860 | 1,071 | 878 | 4,489 |
| 1983 | 1,510 | 0 | 5,123 | 5,520 | 10 | 4,265 | 252 | 2,140 | 0 | 256 | 623 | 27 | 586 | 90 | 3,264 |
| Mean | 8,855 | 2,623 | 9,113 | 6,090 | 278 | 12,968 | 1,278 | 5,773 | 572 | 1,230 | 2,732 | 600 | 2,297 | 1,320 | 13,601 |
| Minimum | 471 | 0 | 1,303 | 265 | 10 | 3,027 | 189 | 461 | 0 | 234 | 623 | 27 | 557 | 90 | 3,264 |
| Maximum | 55,547 | 15,717 | 34,161 | 28,870 | 1,166 | 42,121 | 5,166 | 22,460 | 2,600 | 3,346 | 8,268 | 2,251 | 6,009 | 3,076 | 37,489 |
| SD | 16,593 | 4,721 | 9,217 | 8,477 | 359 | 13,474 | 1,694 | 6,603 | 763 | 1,248 | 2,415 | 788 | 2,061 | 1,073 | 11,126 |
| Total | 88,546 | 26,232 | 91,126 | 60,902 | 2,775 | 129,681 | 12,781 | 57,727 | 5,724 | 12,296 | 27,321 | 5,998 | 22,967 | 13,204 | 136,005 |

Note: Impingement losses expressed as age 1 equivalents are larger than raw losses (the actual number of organisms impinged). This is because the ages of impinged individuals are assumed to be distributed across the interval between the start of year 1 and the start of year 2, and then the losses are normalized back to the start of year 1 by accounting for mortality during this interval (for details, see description of S*j in Chapter A2, Equation 4 and Equation 5). This type of adjustment is applied to all raw loss records, but the effect is not readily apparent among entrainment losses because the majority of entrained fish are younger than age 1
0=Sampled, but none collected.
Wed Feb 13 11:51:10 MST 2002 ;Results; I Plant: brayton.projected ; Units: equivalent.sums Pathname:
P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/I.equivalent.sums.brayton.projected.csv

**Table F3-4: EPA's Estimate of Annual Impingement of Fishery Species at Brayton Point Derived from Historical Impingement Rates Adjusted for Current Operations and Expressed as Yield Lost to Fisheries (in pounds)**

| Year | Atlantic Menhaden | Butterfish | Rainbow Smelt | Silver Hake | Tautog | Weakfish | White Perch | Windowpane | Winter Flounder |
|---|---|---|---|---|---|---|---|---|---|
| 1974 | 1,845 | 10 | 4 | 1,536 | 104 | 131 | 31 | 34 | 2,773 |
| 1975 | 249 | 4 | 0 | 1,654 | 176 | 256 | 23 | 26 | 764 |
| 1976 | 133 | 1 | 1 | 580 | 198 | 151 | 66 | 39 | 1,022 |
| 1977 | 382 | 14 | 1 | 8,543 | 1,312 | 1,572 | 65 | 226 | 2,330 |
| 1978 | 248 | 1 | 6 | 3,779 | 1,211 | 390 | 19 | 285 | 4,037 |
| 1979 | 69 | 3 | 1 | 3,078 | 164 | 224 | 12 | 126 | 661 |
| 1980 | 129 | 29 | 0 | 396 | 331 | 117 | 12 | 172 | 1,277 |
| 1981 | 5 | 2 | 1 | 175 | 378 | 31 | 6 | 224 | 945 |
| 1982 | 19 | 6 | 0 | 1,403 | 1,491 | 1,299 | 12 | 81 | 483 |
| 1983 | 0 | 0 | 0 | 814 | 114 | 19 | 6 | 8 | 351 |
| Mean | 308 | 7 | 1 | 2,196 | 548 | 419 | 25 | 122 | 1,464 |
| Minimum | 0 | 0 | 0 | 175 | 104 | 19 | 6 | 8 | 351 |
| Maximum | 1,845 | 29 | 6 | 8,543 | 1,491 | 1,572 | 66 | 285 | 4,037 |
| SD | 554 | 9 | 2 | 2,512 | 556 | 550 | 23 | 99 | 1,198 |
| Total | 3,080 | 70 | 15 | 21,958 | 5,478 | 4,189 | 253 | 1,223 | 14,645 |

0=Sampled, but none collected.
Wed Feb 13 11:51:28 MST 2002 ;Results; I Plant: brayton.projected ; Units: yield Pathname: P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/I.yield.brayton.projected.csv

**Table F3-5: EPA's Estimate of Annual Impingement at Brayton Point Derived from Historical Impingement Rates Adjusted for Current Operations and Expressed as Production Foregone (in pounds)**

| Year | Alewife | Atlantic Menhaden | Atlantic Silverside | Bay Anchovy | Butter-fish | Hogchoker | Rainbow Smelt | Silver Hake | Striped Killifish | Tautog | Threespine Stickleback | Weakfish | White Perch | Window-pane | Winter Flounder |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 69 | 1,348 | 2 | 0 | 4 | 2 | 21 | 718 | 1 | 40 | 1 | 43 | 99 | 17 | 1,664 |
| 1975 | 54 | 182 | 0 | 4 | 2 | 1 | 1 | 773 | 1 | 67 | 1 | 84 | 74 | 13 | 458 |
| 1976 | 155 | 97 | 1 | 0 | 0 | 4 | 3 | 271 | 4 | 75 | 1 | 50 | 212 | 19 | 613 |
| 1977 | 1,054 | 279 | 1 | 1 | 5 | 19 | 5 | 3,994 | 16 | 499 | 0 | 515 | 210 | 112 | 1,398 |
| 1978 | 87 | 181 | 7 | 0 | 0 | 9 | 30 | 1,767 | 2 | 461 | 0 | 128 | 62 | 141 | 2,422 |
| 1979 | 54 | 50 | 2 | 1 | 1 | 2 | 5 | 1,439 | 3 | 62 | 2 | 73 | 38 | 63 | 397 |
| 1980 | 30 | 95 | 2 | 0 | 11 | 4 | 2 | 185 | 5 | 126 | 0 | 38 | 37 | 85 | 766 |
| 1981 | 9 | 4 | 2 | 0 | 1 | 1 | 4 | 82 | 4 | 144 | 0 | 10 | 20 | 111 | 567 |
| 1982 | 140 | 14 | 1 | 1 | 2 | 14 | 2 | 656 | 1 | 567 | 0 | 425 | 38 | 40 | 290 |
| 1983 | 29 | 0 | 1 | 1 | 0 | 2 | 1 | 381 | 0 | 43 | 0 | 6 | 21 | 4 | 211 |
| Mean | 168 | 225 | 2 | 1 | 3 | 6 | 7 | 1,026 | 4 | 208 | 1 | 137 | 81 | 61 | 879 |
| Minimum | 9 | 0 | 0 | 0 | 0 | 1 | 1 | 82 | 0 | 40 | 0 | 6 | 20 | 4 | 211 |
| Maximum | 1,054 | 1,348 | 7 | 4 | 11 | 19 | 30 | 3,994 | 16 | 567 | 2 | 515 | 212 | 141 | 2,422 |
| SD | 315 | 405 | 2 | 1 | 3 | 6 | 10 | 1,174 | 5 | 212 | 1 | 180 | 73 | 49 | 719 |
| Total | 1,680 | 2,251 | 18 | 8 | 26 | 59 | 74 | 10,265 | 35 | 2,084 | 7 | 1,372 | 810 | 605 | 8,788 |

0=Sampled, but none collected.
Wed Feb 13 11:51:19 MST 2002 ;Results; I Plant: brayton.projected ; Units: annual.prod.forg Pathname: P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/I.annual.prod.forg.brayton.projected.csv

**Table F3-6: EPA's Estimate of Brayton Point Annual Entrainment (numbers of organisms) Derived from Historical Entrainment Rates Adjusted for Current Operations**

| Year | Alewife | American Sand Lance | Atlantic Menhaden | Atlantic Silverside | Bay Anchovy | Hogchoker | Rainbow Smelt | Scup | Seaboard Goby |
|---|---|---|---|---|---|---|---|---|---|
| 1974 | 848,337 | 3,908,121 | 448,538,093 | 25,034,653 | 3,440,864,344 | 0 | 9,317,827 | 0 | 533,634,710 |
| 1975 | 0 | 29,722,440 | 1,958,145,594 | 2,054,000 | 9,286,758,903 | 25,143,906 | 899,822 | 542,291 | 740,278,378 |
| 1976 | 5,913,736 | 2,770,430 | 2,921,793,521 | 51,003,930 | 12,676,121,895 | 150,802,186 | 84,349 | 0 | 894,537,113 |
| 1977 | 1,578,638 | 56,329,070 | 128,713,025 | 10,607,391 | 7,395,970,990 | 88,073,974 | 0 | 0 | 432,875,632 |
| 1978 | 2,091,279 | 60,311,262 | 73,693,538 | 1,542,365 | 8,672,482,263 | 67,483,651 | 1,442,659 | 0 | 289,763,158 |
| 1979 | 0 | 191,610,863 | 115,900,493 | 9,402,729 | 13,609,577,224 | 64,661,257 | 1,420,061 | 0 | 97,031,131 |
| 1980 | 0 | 18,953,510 | 385,593,622 | 6,601,879 | 11,292,722,522 | 259,609,635 | 1,615,204 | 12,750,912 | 291,375,379 |
| 1981 | 0 | 429,543,642 | 3,915,878 | 34,957,087 | 6,349,504,627 | 120,298,108 | 157,396 | 13,221,566 | 524,387,972 |
| 1982 | 262,627 | 21,794,637 | 17,192,935 | 16,515,078 | 11,324,946,303 | 212,128,674 | 91,085 | 1,995,943 | 417,135,869 |
| 1983 | 70,385 | 30,258,451 | 197,688,008 | 29,879,285 | 18,093,306,204 | 77,957,641 | 18,375,305 | 0 | 400,688,890 |
| Mean | 1,076,500 | 84,520,243 | 625,117,471 | 18,759,840 | 10,214,225,528 | 106,615,903 | 3,340,371 | 2,851,071 | 462,170,823 |
| Minimum | 0 | 2,770,430 | 3,915,878 | 1,542,365 | 3,440,864,344 | 0 | 0 | 0 | 97,031,131 |
| Maximum | 5,913,736 | 429,543,642 | 2,921,793,521 | 51,003,930 | 18,093,306,204 | 259,609,635 | 18,375,305 | 13,221,566 | 894,537,113 |
| SD | 1,857,205 | 133,021,447 | 993,768,589 | 16,150,153 | 4,137,368,061 | 81,063,020 | 5,967,035 | 5,378,841 | 229,044,233 |
| Total | 10,765,003 | 845,202,427 | 6,251,174,706 | 187,598,398 | 102,142,255,276 | 1,066,159,032 | 33,403,707 | 28,510,713 | 4,621,708,234 |

0=Sampled, but none collected.
Wed Feb 13 11:40:28 MST 2002 Raw.losses. ENTRAINMENT; Plant:brayton.projected;
PATHNAME:P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/raw.losses.ent.brayton.projected.csv

**Table F3-6: EPA's Estimate of Brayton Point Annual Entrainment (numbers of organisms) Derived from Historical Entrainment Rates Adjusted for Current Operations (cont.)**

| Year | Silver Hake | Tautog | Threespine Stickleback | Weakfish | White Perch | Windowpane | Winter Flounder |
|---|---|---|---|---|---|---|---|
| 1974 | 0 | 4,095,249,317 | 0 | 30,634,273 | 0 | 115,700,207 | 986,595,306 |
| 1975 | 0 | 2,562,125,750 | 0 | 31,509,825 | 0 | 277,646,365 | 859,825,130 |
| 1976 | 0 | 10,513,607,464 | 0 | 0 | 0 | 136,333,892 | 1,217,354,953 |
| 1977 | 0 | 2,178,251,158 | 0 | 14,404,360 | 0 | 101,632,473 | 381,833,868 |
| 1978 | 196,548 | 5,862,184,934 | 0 | 28,303,368 | 57,788 | 590,926,739 | 1,359,249,041 |
| 1979 | 0 | 3,132,662,371 | 0 | 83,878,964 | 330,550 | 527,866,367 | 668,918,507 |
| 1980 | 0 | 2,635,758,729 | 0 | 344,491,911 | 0 | 510,692,636 | 724,134,196 |
| 1981 | 0 | 1,128,620,504 | 0 | 40,293,328 | 0 | 257,717,460 | 356,754,776 |
| 1982 | 115,756 | 2,517,050,246 | 167,498 | 59,283,063 | 49,320 | 698,080,809 | 1,127,118,545 |
| 1983 | 122,201 | 4,911,927,271 | 0 | 31,941,824 | 112,843 | 466,673,500 | 277,046,674 |
| Mean | 43,450 | 3,953,743,774 | 16,750 | 66,474,092 | 55,050 | 368,327,045 | 795,883,100 |
| Minimum | 0 | 1,128,620,504 | 0 | 0 | 0 | 101,632,473 | 277,046,674 |
| Maximum | 196,548 | 10,513,607,464 | 167,498 | 344,491,911 | 330,550 | 698,080,809 | 1,359,249,041 |
| SD | 73,094 | 2,690,678,198 | 52,967 | 100,344,139 | 104,064 | 216,770,630 | 380,047,652 |
| Total | 434,505 | 39,537,437,744 | 167,498 | 664,740,916 | 550,501 | 3,683,270,450 | 7,958,830,996 |

0=Sampled, but none collected.
Wed Feb 13 11:40:28 MST 2002 Raw.losses. ENTRAINMENT; Plant:brayton.projected;
PATHNAME:P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/raw.losses.ent.brayton.projected.csv

**Table F3-7: EPA's Estimate of Annual Entrainment at Brayton Point Derived from Historical Entrainment Rates Adjusted for Current Operations and Expressed as Age 1 Equivalents**

| Year | Ale-wife | American Sand Lance | Atlantic Menhaden | Atlantic Silverside | Bay Anchovy | Hog-choker | Rainbow Smelt | Scup | Seaboard Goby | Silver Hake | Tautog | Threespine Stickleback | Weak-fish | White Perch | Window-pane | Winter Flounder |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 528 | 20,985 | 15,764 | 10,849 | 471,088 | 0 | 20,403 | 0 | 1,749,359 | 0 | 30,833 | 0 | 563 | 0 | 2,518 | 27,124 |
| 1975 | 0 | 159,598 | 43,032 | 890 | 1,213,596 | 8,613 | 4,812 | 394 | 2,426,777 | 0 | 20,864 | 0 | 579 | 0 | 6,108 | 115,620 |
| 1976 | 1,580 | 14,876 | 32,550 | 22,103 | 1,161,615 | 43,421 | 1,022 | 0 | 2,922,733 | 0 | 78,264 | 0 | 0 | 0 | 2,959 | 131,571 |
| 1977 | 982 | 302,466 | 2,671 | 4,597 | 954,624 | 34,152 | 0 | 0 | 1,419,051 | 0 | 16,686 | 0 | 265 | 0 | 2,311 | 31,646 |
| 1978 | 1,301 | 317,798 | 939 | 668 | 1,462,657 | 24,687 | 12,476 | 0 | 949,612 | 10 | 45,078 | 0 | 520 | 0 | 12,195 | 1,866,911 |
| 1979 | 0 | 1,028,877 | 1,527 | 2,927 | 1,483,081 | 22,544 | 29,920 | 0 | 318,087 | 0 | 23,962 | 0 | 500 | 1 | 10,237 | 691,878 |
| 1980 | 0 | 101,773 | 5,974 | 2,822 | 1,120,273 | 81,165 | 34,032 | 1,812 | 955,185 | 0 | 21,101 | 0 | 1,757 | 0 | 9,942 | 559,826 |
| 1981 | 0 | 2,306,485 | 69 | 15,074 | 644,120 | 38,212 | 3,316 | 1,879 | 1,719,046 | 0 | 8,499 | 0 | 226 | 0 | 4,850 | 332,930 |
| 1982 | 163 | 117,029 | 187 | 7,129 | 1,651,529 | 64,000 | 1,919 | 1,008 | 1,365,625 | 5 | 19,471 | 6,526 | 345 | 0 | 13,507 | 805,497 |
| 1983 | 44 | 162,476 | 2,515 | 12,931 | 2,147,915 | 24,687 | 387,158 | 0 | 1,312,882 | 1 | 36,732 | 0 | 161 | 0 | 9,064 | 508,141 |
| Mean | 460 | 453,236 | 10,523 | 7,999 | 1,231,050 | 34,148 | 49,506 | 509 | 1,513,836 | 2 | 30,149 | 653 | 492 | 0 | 7,369 | 507,114 |
| Minimum | 0 | 14,876 | 69 | 668 | 471,088 | 0 | 0 | 0 | 318,087 | 0 | 8,499 | 0 | 0 | 0 | 2,311 | 27,124 |
| Maximum | 1,580 | 2,306,485 | 43,032 | 22,103 | 2,147,915 | 81,165 | 387,158 | 1,879 | 2,922,733 | 10 | 78,264 | 6,526 | 1,757 | 1 | 13,507 | 1,866,911 |
| SD | 610 | 714,399 | 15,293 | 7,076 | 488,813 | 24,349 | 119,279 | 774 | 748,897 | 3 | 19,866 | 2,064 | 484 | 0 | 4,152 | 553,383 |
| Total | 4,597 | 4,532,363 | 105,229 | 79,992 | 12,310,498 | 341,480 | 495,058 | 5,093 | 15,138,358 | 17 | 301,490 | 6,526 | 4,917 | 1 | 73,691 | 5,071,144 |

0=Sampled, but none collected.
Wed Feb 13 11:51:07 MST 2002 ;Results; E Plant: brayton.projected ; Units: equivalent.sums Pathname:
P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/E.equivalent.sums.brayton.projected.csv

**Table F3-8: EPA's Estimate of Annual Entrainment of Fishery Species at Brayton Point Derived from Historical Entrainment Rates Adjusted for Current Operations and Expressed as Yield Lost to Fisheries (in pounds)**

| Year | Atlantic Menhaden | Rainbow Smelt | Scup | Silver Hake | Tautog | Weakfish | Windowpane | Winter Flounder |
|---|---|---|---|---|---|---|---|---|
| 1974 | 1,851 | 23 | 0 | 0 | 13,737 | 393 | 233 | 2,921 |
| 1975 | 5,053 | 5 | 41 | 0 | 9,296 | 404 | 566 | 12,450 |
| 1976 | 3,822 | 1 | 0 | 0 | 34,870 | 0 | 274 | 14,167 |
| 1977 | 314 | 0 | 0 | 0 | 7,434 | 185 | 214 | 3,408 |
| 1978 | 110 | 14 | 0 | 4 | 20,084 | 363 | 1,130 | 201,025 |
| 1979 | 179 | 34 | 0 | 0 | 10,676 | 349 | 948 | 74,500 |
| 1980 | 701 | 39 | 190 | 0 | 9,401 | 1,227 | 921 | 60,281 |
| 1981 | 8 | 4 | 197 | 0 | 3,787 | 158 | 449 | 35,849 |
| 1982 | 22 | 2 | 106 | 2 | 8,675 | 241 | 1,251 | 86,734 |
| 1983 | 295 | 440 | 0 | 1 | 16,366 | 112 | 840 | 54,716 |
| Mean | 1,236 | 56 | 53 | 1 | 13,433 | 343 | 683 | 54,605 |
| Minimum | 8 | 0 | 0 | 0 | 3,787 | 0 | 214 | 2,921 |
| Maximum | 5,053 | 440 | 197 | 4 | 34,870 | 1,227 | 1,251 | 201,025 |
| SD | 1,796 | 136 | 81 | 1 | 8,851 | 338 | 385 | 59,587 |
| Total | 12,356 | 563 | 535 | 6 | 134,326 | 3,434 | 6,826 | 546,050 |

0=Sampled, but none collected.
Wed Feb 13 11:51:26 MST 2002 ;Results; E Plant: brayton.projected ; Units: yield Pathname: P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/E.yield.brayton.projected.csv

**Table F3-9: EPA's Estimate of Annual Entrainment at Brayton Point Derived from Historical Entrainment Rates Adjusted for Current Operations and Expressed as Production Foregone (in pounds)**

| Year | Ale-wife | American Sand Lance | Atlantic Menhaden | Atlantic Silverside | Bay Anchovy | Hog-choker | Rain-bow Smelt | Scup | Sea-board Goby | Silver Hake | Tautog | Threespine Stickleback | Weakfish | White Perch | Window-pane | Winter Flounder |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1974 | 563 | 80 | 727,705 | 11,798 | 482,933 | 0 | 3,635 | 0 | 886 | 0 | 62,594,114 | 0 | 401,167 | 0 | 56,227 | 5,589,405 |
| 1975 | 0 | 605 | 2,122,523 | 968 | 1,326,997 | 18,901 | 551 | 23 | 1,230 | 0 | 38,915,872 | 0 | 412,633 | 0 | 134,698 | 6,162,398 |
| 1976 | 2,623 | 56 | 1,872,731 | 24,036 | 2,013,015 | 118,326 | 92 | 0 | 2,466 | 0 | 160,835,134 | 0 | 0 | 0 | 66,285 | 8,273,869 |
| 1977 | 1,047 | 1,147 | 133,060 | 4,999 | 1,061,663 | 63,806 | 0 | 0 | 719 | 0 | 33,249,061 | 0 | 188,630 | 0 | 49,040 | 2,460,091 |
| 1978 | 1,387 | 1,392 | 52,050 | 727 | 1,104,995 | 49,782 | 1,219 | 0 | 510 | 572 | 89,454,342 | 0 | 370,643 | 76 | 289,536 | 6,696,994 |
| 1979 | 0 | 3,901 | 83,937 | 3,616 | 2,065,095 | 48,369 | 2,443 | 0 | 161 | 0 | 47,822,827 | 0 | 3,338,452 | 433 | 260,963 | 3,063,855 |
| 1980 | 0 | 386 | 315,765 | 3,084 | 1,758,507 | 199,834 | 2,779 | 8,110 | 484 | 0 | 40,090,691 | 0 | 14,349,676 | 0 | 252,339 | 3,294,944 |
| 1981 | 0 | 8,745 | 3,550 | 16,421 | 982,948 | 92,237 | 271 | 8,409 | 871 | 0 | 17,250,213 | 0 | 1,633,686 | 0 | 127,934 | 1,688,902 |
| 1982 | 174 | 444 | 10,852 | 7,763 | 1,548,304 | 164,685 | 157 | 533 | 877 | 305 | 38,391,085 | 278 | 2,377,063 | 65 | 345,225 | 5,195,371 |
| 1983 | 47 | 616 | 139,510 | 14,069 | 2,673,623 | 59,819 | 31,613 | 0 | 731 | 207 | 75,115,592 | 0 | 1,334,689 | 148 | 230,663 | 1,379,929 |
| Mean | 584 | 1,737 | 546,168 | 8,748 | 1,501,808 | 81,576 | 4,276 | 1,707 | 894 | 108 | 60,371,893 | 28 | 2,440,664 | 72 | 181,291 | 4,380,576 |
| Minimum | 0 | 56 | 3,550 | 727 | 482,933 | 0 | 0 | 0 | 161 | 0 | 17,250,213 | 0 | 0 | 0 | 49,040 | 1,379,929 |
| Maximum | 2,623 | 8,745 | 2,122,523 | 24,036 | 2,673,623 | 199,834 | 31,613 | 8,409 | 2,466 | 572 | 160,835,134 | 278 | 14,349,676 | 433 | 345,225 | 8,273,869 |
| SD | 872 | 2,705 | 796,209 | 7,663 | 641,950 | 63,106 | 9,692 | 3,458 | 623 | 196 | 41,188,478 | 88 | 4,321,715 | 136 | 107,393 | 2,325,539 |
| Total | 5,841 | 17,371 | 5,461,683 | 87,480 | 15,018,080 | 815,760 | 42,760 | 17,074 | 8,936 | 1,083 | 603,718,930 | 278 | 24,406,639 | 721 | 1,812,911 | 43,805,757 |

0=Sampled, but none collected.
Wed Feb 13 11:51:17 MST 2002 ;Results; E Plant: brayton.projected ; Units: annual.prod.forg Pathname: P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/E.annual.prod.forg.brayton.projected.csv

**Table F3-10: Average Annual Impingement and Entrainment at Brayton Point (sum of annual means of all species evaluated)**

| | Impingement | Entrainment |
|---|---|---|
| Raw losses (# of organisms) | 44,752 | 16,703,221,011 |
| Age 1 equivalents (# of fish) | 69,329 | 3,847,045 |
| Fishery yield (lb of fish) | 5,091 | 70,410 |
| Production foregone (lb of fish) | 2,808 | 69,522,130 |

mixed.rollup.chap3.imp Wed Feb 13 13:28:53 MST 2002
P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/flowchart.chap3.IMP.csv
mixed.rollup.chap3.ent Wed Feb 13 13:28:54 MST 2002
P:/Intake/Brayton/Brayton_Science/scodes/tables.output.projected01/flowchart.chap3.ENT.csv